A STUDY OF THE EFFECTS OF VIRTUAL REALITY ON THE RETENTION OF TRAINING

by

CARL R. JACQUET
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Abstract
Todays faster processors, powerful graphics boards, and less-expensive head-mounted displays have made virtual reality (VR) a possible replacement for PC-based desktop simulation. Do virtual reality systems using head-mounted displays offer training advantages to systems using regular, non-immersive interfaces? Specifically, does a virtual reality training system increase retention of the trained task, versus a desktop simulation system? The retention of tasks learned in a virtual reality training environment by 16 subjects was studied in comparison to 16 subjects in a desktop simulation environment in the context of a part-task, maintenance training system. Measures of training retention included time to complete the task and procedural errors observed. Although the findings indicate that the difference found between the experimental groups was not statistically significant, the foundation has been laid for further study of the effects of the increased contextual cues present in virtual reality environments.

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ABSTRACT

Today's faster processors, powerful graphics boards, and less-expensive head-mounted displays have made virtual reality (VR) a possible replacement for PC-based desktop simulation. Do virtual reality systems using head-mounted displays offer training advantages to systems using regular, non-immersive interfaces? Specifically, does a virtual reality training system increase retention of the trained task, versus a desktop simulation system? The retention of tasks learned in a virtual reality training environment by 16 subjects was studied in comparison to 16 subjects in a desktop simulation environment in the context of a part-task, maintenance training system. Measures of training retention included time to complete the task and procedural errors observed. Although the findings indicate that the difference found between the experimental groups was not statistically significant, the foundation has been laid for further study of the effects of the increased contextual cues present in virtual reality environments.

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CHAPTER ONE. INTRODUCTION

Current personal computer graphics cards coupled with 1 Gigahertz and faster central processing units have allowed the migration of Virtual Reality (VR) training into disciplines not previously considered appropriate. In the area of maintenance training, these systems can allow training to be conducted on systems that are not physically available. These new systems can also train mechanics to trouble-shoot and fix problems on systems that are not easily replicated, at much less cost than full-scale mock-up training systems. Current Head-Mounted Display (HMD) technology allows a user to wear lightweight, wireless goggles and view greater than 800 x 600 resolution images. These HMDs combined with a three-dimensional (3D) mouse or a data-glove can create a feeling of immersion.

Immersion according to Witmer and Singer (1998, p. 227) is “a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences.” Sadowski & Stanney (2002) further note that Witmer and Singer suggest that factors of immersion include isolation from the real world environment, perception of self-inclusion in the Virtual Environment (VE), the use of natural modes of interaction, and the perception of self-movement (p. 3). Sadowski & Stanney (2002) state that other researchers including Slater and Wilbur (1997), Draper, Kaber, and Usher (1998), Bystrom, Barfield, and Hendrix (1999), believe that immersion is based solely on the technological aspects of the system producing the environment. In other words, to be immersive, a system must possess a high-resolution display with a wide field of view. The system must also isolate the user from real world sensations such as light and sound to allow the user to become a participant in the VE, and not simply an observer of it.

Many authors such as Psotka (1995) believe the cognitive effects of an immersive environment can be attributed to the isolation from the surrounding world's visual, audible, and kinesthetic sensations, while also presenting an egocentric experience not unlike the real world. The term that describes this sensation in VR is presence. Presence is not simply the amount of immersion, though. The degree of immersion affects the amount of presence one may feel interacting with the virtual environment (VE), but an immersive environment may not have a high level of presence, if the VE does not resemble the real world environment closely enough. Immersion more closely describes the physical hardware attributes of the system, while presence describes the cognitive feeling that "I am there." Many authors define presence as the perception of participating in and existing within a virtual environment "in which one is immersed" (Heeter, 1992; Sheridan, 1992; Steuer, 1992; Witmer & Singer, 1998). Barfield and Hendrix (1995) state that humans can distinguish presence felt in virtual environments from that in the real world by the extent that participants in a computer generated simulation believe they are at a time and place depicted in the simulation, versus their real world time and location. Singer and Witmer (1997) suggest presence is based on "interactions of sensory stimulation, environmental factors, and internal tendencies." Kim and Biocca (1997) suggest presence is a function of "arrival" and "departure" of experience in the VE. "Arrival" involves focusing on the VE's stimuli, while departure is the shift of attention from the VE stimuli to the real world. Sadowski and Stanney (2002) follow that increasing one's attention and focus on a VE increases involvement, thus increasing presence.

There are many variables, both internal and external, that affect presence. Stanney, Mourant, and Kennedy (1998) and Slater and Usoh (1993) list the variables as: 1) ease of interaction; 2) user-initiated control; 3) pictorial realism; 4) length of exposure; 5) social factors; and 6) system factors. Social factors describe the effect that the existence of others in the environment increases the environment's realism, while internal factors describe each individual's perception of the environment (Steuer, 1992; Heeter, 1992). Slater and Usoh (1993) describe system factors as the fidelity of the replicated environment, the method of presentation to the user, and the method of user interaction. Slater and Usoh (1993) suggest a positive relationship exists between the realism of the depiction, and associated presence felt by the user.

Though many theorize that presence may positively affect human performance, there exists conflicting evidence that it does (Sadowski and Stanney, 2002). None question the captivating effect of presence, though, as customers flock to VR entertainment devices at Disney Quest® and other theme parks to experience these immersive environments. However, to be useful in a training environment, and to justify the added expense of high-resolution graphics, HMDs, and realistic interfaces such as data gloves, VR must give an added value to training. Measuring the actual presence generated by a training system thus becomes moot, if the system does not improve training and generate added value.

The existence of training transfer from VEs to the real world is not well documented. The evidence supporting the existence of transfer frequently conflicts with evidence supporting its non-existence. In many cases, those in the real world learn the task better than those trained in virtual reality (Kozak, Hancock, Arthur, & Chrysler, 1993). In other cases, where subjects executed a simple spatial task (Rose, Attree, Brooks, Parslow, Penn, & Ambihaipahan, 2000), performed aircraft maintenance (Barnett, Perrin, Curtin and Helbing, 1998), or practiced using forestry machinery (Lapointe & Robert, 2000), there was no significant difference found between those trained using the real world equipment, and those trained in VR.

Although it is given that VR training can be effective, how does training conducted with desktop simulation, a "poor man's virtual reality" utilizing a conventional computer screen, keyboard, and mouse; compare with training conducted in virtual reality using a head mounted display and a 3D mouse? The cost benefits would obviously be in favor of the "poor man's virtual reality" devices for some tasks. It can be predicted that both a desktop simulation system and a VR system will each transfer skills to the real world. However, are there any further advantages to using VR? One possible benefit from the VR consistent with the concept of presence is that virtual environments contain a greater number of spatial cues characteristic of the real world environment as compared to the desktop display. The spatial arrangement of objects in a VE is very similar to the arrangement in the real world. The spatial cues of a 3D world projected onto a flat display do not give the same sense of spatial arrangement. Do these cues present in VR, but not in desktop simulation, increase the comparative effectiveness of a VR system over a desktop simulation system? Under the ACT-R model (Anderson & Lebiere, 1998), increased contextual cues relative to a task environment should add to the retention or strength of memory traces and thus affect the retention of trained task knowledge.

Consequently, given an increased number of task relevant contextual cues represented in a VR environment versus that of the desktop display simulation, one would predict from ACT-R (Anderson & Lebiere, 1998), greater retention for tasks trained in VR versus a desktop panel display replica of the task environment. In the context of testing whether or not an immersive virtual reality tank maintenance training system improves retention versus a desktop simulation with a monitor and mouse, the following research question emerges: *Is there a significant improvement in retention associated with upgrading an existing M1 Tank Maintenance Trainer environment to an immersive, three-dimensional environment?* The following paragraphs discuss retention, virtual environment effects on cognition, and methodology and findings from an experiment that tested the effects of virtual reality on human retention for a tank maintenance task.

CHAPTER TWO: BACKGROUND LITERATURE

Learning and Retention

To maximize learning, one must understand learning itself. Anderson (1995) defines learning as "the process by which relatively permanent changes occur in behavioral potential as a result of experience" (p. 4). Retention refers to one's ability to recall, or remember information, and is thus related to memory. Anderson (1995) defines memory as "the relatively permanent record of the experience that underlies learning" (p. 5).

While learning is important, the ability to recall the learned information at a time and place useful to the individual is paramount to training for a specific task. The study of retention is also the study of forgetting. Several hypotheses exist to explain forgetfulness. They are the decay hypothesis (Wickelgren, 1976), the interference hypothesis (Keppel and Underwood, 1962), and the retrieval-cue hypothesis (Tulving and Psotka, 1971). While the decay hypothesis states that memories weaken over time (Wickelgren, 1976), the interference hypothesis asserts that memories compete against each other and block retrieval of a specific memory (Keppel and Underwood, 1962), and the retrieval-cue hypothesis states that we lose the cues or keys to the memory at the time of retrieval (Tulving and Psotka, 1971). The retrieval-cue hypothesis (Tulving and

Psotka, 1971) is interesting due to its similarity to Anderson's ACT-R model, which describes humans accessing memory via specific contextual cues. Similar to the retrieval-cue hypothesis is the principle of encoding specificity. Encoding specificity states that the memories are best retrieved when the conditions for retrieval are most like the conditions were when they were encoded (Tulving & Thompson, 1971). Contextual cues, though not identical to configural cues of classical conditioning, can be likened to them for purpose of comparison (Anderson, 1995). Contextual and configural cues are the combination of stimuli, specific to the environment in which the behavior is learned. Configural cues are key to the recall of the information, or the triggering of the behavior. Anderson's (1998) ACT-R model describes activation of a memory structure with the following equation (Anderson & Lebiere, 1998):

$$A_i = B_i + \sum_j W_j S_{ji} \tag{1}$$

Where A_i is the activation the memory chunk i, and represents the strength of a declarative memory element. B_j is the chunk's base level of activation. Base level activation is a function of the frequency of usage of the chunk and the time lag between uses of the chunk. W_j reflects the attentional weighting or salience of an element of information associated with a declarative chunk (i.e., a contextual cue). The S_{ji} terms are the strength of the association of the contextual cues to the chunk (Anderson & Lebiere, 1998). One can also gather that the more specific contextual cues present that relate to a chunk, the more activation the chunk in memory will receive.

Assuming that a virtual environment accurately modeled after a real environment possesses an increased number of specific contextual cues relative to the training task, compared to a desktop simulation of the same environment, the training conducted in such an immersive environment should yield better retention than a desktop simulation of the same environment. Some of the increased contextual cues in the virtual environment would include the spatial relationships in the task environment, such as the location of items in the turret with relation to each other and with oneself. Instead of looking at a flat picture of an environment, the individual immersed in a virtual environment can reach out and experience the spatial dimensions of the world, and sense the spatial relationships between objects. Because this environment contains more real world-like spatial cues, memories from this task environment may be more readily activated when the individual encounters the real world task environment. Increased activation should lead to less time on task, and improved retention of task knowledge.

Advantages of New Technology

As powerful computer graphics boards become less expensive, more and more educators and trainers are choosing virtual reality as the medium to present information. Consumer graphics boards incorporating NVIDIA® GeForce4™ chipsets now compare very favorably with high-end Wildcat® cards at a small fraction of the cost. The appearance of this low-cost technology in the marketplace has enabled budget-constrained industries to embrace VR. From non-invasive heart surgery to curing phobias, uses of Head Mounted Displays (HMD) and Data Gloves are multiplying rapidly (Vince, 1999).

Seeking to improve the efficiency of training mechanics for the M1A2 System Enhancement Program (SEP) Main Battle Tank and to capitalize on emerging commercial technologies, the U.S. Army Tank and Automotive Command (TACOM) has initiated an experiment to test whether a virtual, immersive training system is more effective in training mechanics than a similar VR system that uses a non-immersive interface. The proposed system, called the Virtual Immersive Maintenance Trainer (VIMT), uses commercial, off-the-shelf components to keep the cost of each system down under $20 thousand. The company producing the VIMT, Veridian Information Solutions (VIS), believes that the VIMT will improve training effectiveness for students using the system. In addition, VIS believes that the students will have greater spatial knowledge of the M1A2 tank when working on the actual system, than if they were only exposed to a non-immersive desktop simulation system (Veridian, 2001).

Past Experience with VR Training

Knerr, Lampton, Singer, Witmer, Goldberg, Parsons, and Parsons (1998) found that VR can improve spatial awareness in navigational tasks, and that VR aids in acquiring configuration knowledge. Knerr et al. (1998) do not specify whether or not the spatial relationship of a tank turret will be helpful in learning turret system trouble-shooting and maintenance procedures. However, the report does specify what types of tasks immersive environments are suitable to train. Knerr et al. (1998) state that VR systems are not suitable for "…tasks that involve precise or rapid motor activity" (p. 54). Veridian's proposed VIMT does not require rapid motor activity (See Appendix B for task list), but virtual reality historically has not performed well in tasks that do not require navigation of terrain or buildings.

Although the ARI report does not specifically address the same type of tasks that will be trained on the VIMT, Knerr et al. (1998) commented that virtual reality works best training tasks that require spatial awareness, such as navigation in a building or a maze. Knerr (2001) states an example of a maintenance task that may train well in virtual reality would be the act of removing a vehicle's engine from its engine bay. The mechanic must ensure that the engine clears the mounts and fenders while hoisting it from the vehicle. HMDs aid realism for this task by allowing the user to change perspective at will, by moving their head side to side and in the vertical plane to gauge depth and clearance between objects more accurately. Burns and Patrey (2000) corroborate Knerr et al. (1998) on appropriate training tasks for immersive VR systems. Burns and Patrey (2000) compare immersive VR techniques to non-immersive techniques in the context of a naval at-sea replenishment scenario. Results of the experiment indicate that officers using an HMD gained better perception of lateral spacing of the ships, than those performing the task with a regular CRT screen interface.

Troubleshooting in a tank turret requires some spatial awareness of the location of components, but for the most part, is a procedural task. Since the VIMT does not train tasks that require exact spatial awareness or navigation skills, the involved parties stood uncertain whether the VIMT would improve training effectiveness over the desktop simulation, until research confirmed or denied it.

Evaluating Training in Virtual Environments

Lathan, Tracey, Sebrechts, Clawson, and Higgins (2002) discuss various methods to measure transfer from a virtual environment to the real task. In addition, Lathan et al. (2002) list a method to test a newly developed simulator versus an existing simulator. Their Transfer of Training Method requires two groups, with the experimental group being participants trained on the new simulator, and the control group training on the existing system. The two groups' performance on the real world task was compared to determine the degree of improvement (if any) that the new simulator yields. Adding a retention test following a period of inactivity to the transfer of training test above would allow the measurement of retention of the trained task on the real world system.

Transfer of Training from Virtual Environments

A few authors have researched the transfer that occurs from tasks performed in Virtual Environments to the same tasks performed in the real world. Kozak, Hancock, Arthur, and Chrysler (1993) found that real-world training proved significantly better in transfer than did virtual reality training in a simple pick and place task of moving five empty soda cans to and from rows of target locations in sequence. The two target rows were separated by six inches. In the case of the Kozak et al. (1993) study, the group that trained in virtual reality did not perform significantly different from the group that had no training at all. Kozak et al. (1993) also state that the lack of transfer from the VR may be due to its lack of fidelity (limited by the then-current technology) to the real world environment. Psotka (1995) attributes the lack of transfer found in the Kozak et al.

(1993) study to the simplicity of the task tested, and that a more difficult task may have shown transfer.

In the past eight years, computer technology has improved to allow for an increase in the fidelity of virtual environments. In more recent studies, the gap between VR training and real-world training has closed significantly. As an example, Rose et al. (2000) found no significant difference in post-training performance when training with VR and real-world venues on a steadiness task (i.e., requiring one to maneuver a ring over a bent wire without touching the ring to the wire). The study by Rose, et al. (2000) reinforces the idea that the quality of the simulation and training conducted in the VR trainer affect the amount of skill transfer that takes place between the artificial environment and the real world. In a separate study, Barnett, Perrin, Curtin, and Helbing (1998) also concluded that training motor skills in VR and real-world environments yielded statistically similar results. The near-equality of VR and real world training for specific tasks presents a great advantage for training expensive or dangerous activities.

Lapointe and Robert (2000) found that using a VR Forestry Machine Trainer decreased the necessary training time of new operators, and increased the initial productivity output of the trainees, once they transitioned to the actual machine. Their studies showed that using VR for the initial training of new operators reduced repair and maintenance costs by 26 percent, and increased production by 23 percent during the new operators' first month of actual work with the forestry machines.

The task of tank turret troubleshooting differs from the forestry task studied by Lapointe and Robert (2000) in that it requires less spatial awareness, and slightly more procedural knowledge.

In any case, to be effective, a VR training system must adequately represent the task or tasks to be trained (i.e., provide sufficient contextual cues relative to the task or goal at hand), and provide adequate feedback to the student on their performance in the training system. Although the studies above have shown that training on specific tasks conducted in VR does transfer positively to the real world, this should not be a carte blanche acceptance of VR for training tasks in general. Additionally, there are cost benefits interactions that must be taken into account when deciding upon the appropriateness of VR for training specific tasks. Additional experimentation must be performed in order to judge whether a VR model of an environment enables a trainee to retain and transfer more knowledge than does a desktop simulation model of the same environment, especially given the cost differential between these two modes of task environment simulation.

Retention of Tasks within Virtual Environments

Finkelstein (1999) studied the retention of tasks within virtual environments and developed twelve guidelines to aid in task retention. Though interesting, Finkelstein's research focused on the retention of tasks *within* a virtual environment following a one-week delay, versus the concern of this study, which is the retention of tasks transferred to the real world environment. In his findings, Finkelstein attributes an increase in retention to the amount of “guidelines” (landmarks, imbedded photos of movie characters, and other salient features) included in the VE.

Finkelstein’s (1999) finding that adding “guidelines” increases retention parallel the assertions of Anderson’s and Lebiere’s (1998) ACT-R model, that notes an increase in retention with an increase in associated contextual cues. Since Finkelstein’s “guidelines” add such cues to the environment, then by Anderson’s and Lebiere’s (1998) ACT-R model, they should increase retention of the task when tested outside of the VR environment.

CHAPTER THREE: METHOD

Research Question: Is there a significant improvement in retention associated with upgrading the existing M1A2 System Enhancement Program (SEP) Tank Maintenance Trainer environment to an immersive, three-dimensional environment?

In order to answer the above research question, an experiment was conducted to test whether or not using the three-dimensional immersive environment of the Virtual Immersive Maintenance Trainer increases retention in subjects, in comparison to those subjects using the desktop simulation version of the trainer.

Task

The training systems compared, train diagnosing and trouble-shooting turret malfunctions in a M1A2-SEP Tank. The tasks selected for the experiment was the Weapon System Internal Fault Isolation Test (InterFIT). The InterFIT is a relatively stationary task inside the tank turret requiring the reading of displays and manipulation of controls. The Weapon System InterFIT was chosen because it requires the mechanic to traverse the space of the turret repeatedly to manipulate controls and check the status of lights and displays. The task does not require rapid head or body movement, though the subject must operate and view devices from many viewpoints and positions within the turret. It is a generally a procedural task requiring some knowledge of the spatial arrangement of the components of the tank turret.

The desktop simulation subjects performed the two tasks while using the desktop diagnostic/troubleshooting trainer. They activated switches and buttons using a point-and-click interface via a Microsoft® Wheel Mouse. In order to use a tool to remove a part, the soldier clicks on a tool icon, which turns his cursor into a wrench, and then allows him to remove or replace selected parts with a single mouse click. The desktop subjects change the view of the interior of the turret by clicking on graphical buttons displayed on a toolbar at the bottom of the screen. Each direction of movement or rotation (six degrees of freedom) is represented by its own arrow icon.

The VR subjects performed the task on the VIMT, using a point-and-click interface to activate switches and buttons via a Polhemus® 3Ball 3D mouse. The VR subjects changed their view of the turret by moving or rotating their head in the desired direction. The VIMT tracks head movement in six degrees of freedom. The VIMT provides an immersive 3D representation of the tank turret environment versus the desktop flat panel display portraying the same equipment information in the absence of holistic configuration of turret spatial relations.

Subjects

The 32 subjects selected for the experiment were all students in a United States Army M1A2 SEP tank mechanic training course. They are all enlisted soldiers in Military Occupational Specialty 63A (Abrams Tank Systems Mechanic), ranging in age from 18 to 32 years, with an average age of 20.9 years (See Table G-1 in Appendix G). All of the subjects are male. Nineteen subjects are Caucasian, eight are Hispanic, and five are black. All of the subjects have a high school level education or better. All of the subjects, except one, were new enlistees who have been training on M1 tanks for 4 months, and have been selected to receive training on the newest version of the M1 tank, the M1A2 SEP. The one exception is a fourteen-year veteran tank mechanic previously untrained on the M1A2 SEP tank, but very experienced on the older versions of the armored vehicle.

The class was divided evenly by their grades to date in their ten-month training program, placing equal numbers of high (above 85 % test scores) and low scoring students (several test scores below 70 %) in each experimental group. The veteran mechanic was considered a high scoring student, and was placed in the experimental group.

Materials

The two different devices used in the experiment were the existing M1A2 SEP Diagnostic Troubleshooting trainer (See Figure 1), and the Virtual Immersive Maintenance Trainer prototype (See Figure 2).

Figure 1. M1A2 SEP Diagnostic Trainer (Desktop Simulation)

The desktop simulation trainer uses 1280 x 1024 graphic resolution produced by a Silicon Graphics workstation displayed on two monitors (See Table 1 for system specifications). The right monitor (See Figure 1) displays a three-dimensional view of the inside of the tank turret, while the left display presents a detailed, two-dimensional view of a user-selected computer display screen in the turret. Unlike in the real tank, the three-dimensional (right-hand screen) view on the desktop simulation system does not depict data that would be presented on the vehicle's computer displays in the real tank. To see data on the tank computer screens, the user must view the left CRT display (2D view). The user interface for the desktop simulation system is a conventional mouse and a 101-key keyboard.

Table 1. M1A2 SEP Desktop Simulation Trainer System Specifications

System		
	Processors	Dual 866MHz Pentium®III
	System Memory	1.5 GB RAM (SD133)
	Operating System	MS Windows® 2000
	Graphics Processor	Intense3D® Wildcat® 4210
	Resolution	1280 x 1024
Display		
	Manufacturer	CTX®
	Model	Two VL950 CRT Monitors (19 in)
	Pitch	0.26 mm
Mouse		
	Manufacturer	Microsoft™
	Model	Intellimouse® with wheel

The VIMT prototype (See Figure 2) uses a Cy-visor™ DH-4400VP HMD with 800 x 600 resolution and a 31 degree diagonal field-of-view (25 degree Horizontal field-

Figure 2. M1A2 SEP Virtual Immersive Maintenance Trainer

of-view). The DH-4400VP allows adjustment of its screens' inter-pupillary distance (IPD). It does not possess diopter adjustments. These 3D goggles do accommodate the wear of eyeglasses through interchangeable eyecups, which allow additional clearance with the user's face. Although the HMD used has a relatively small field-of-view, its dual displays contain 1.44 million pixels each, allowing sufficient resolution to read all labels and displays present in the virtual environment. The virtual reality trainer uses a three-dimensional mouse as its interface, and navigation in the VE is performed by the subject rotating or moving his head with 6 degrees-of-freedom. Additionally, a conventional computer monitor is present to allow an instructor or observer to track what the user is viewing in the three-dimensional space (See Figure 2). Unlike the desktop simulation system, which uses two screens, the VIMT's graphics depict the tank's computer screens as they would appear in the real tank, complete with textual and graphical data. See Table 2 (next page) for the VIMT system's specifications.

Table 2. VIMT System Specifications

System	
Processor	Dual AMD Athlon™ 1.533MHz
System Memory	785.9 MB RAM
Operating System	MS Windows® 2000, Ver. 5.002195 (SP2)
Graphics Processor	NVIDIA™ Geforce3® Ti 500
Resolution	800 x 600
Display (HMD)	
Manufacturer	Personal Display Systems, Inc.
Model	I-Visor® DH-4400VP
LCD	0.49in, 1.44 million pixels
Dot number / panel	800 (H) x 600 (V) x RGB
Virtual Image Size	44in. at 2m
Viewing Angle	31 deg. diag. (HFOV 25 deg.)
PC Input	RGB
Mouse (3D)	
Manufacturer	Polhemus®
Model	3Ball®
VR Tracker	
Manufacturer	Polhemus®
Model	3 Space Fastrack® Receiver
Latency	4ms
Update Rate	120Hz
VGA Splitter	
Manufacturer	ATEN®
Model	VS104 VGA Splitter

Procedure

The experiment utilized a two-group design, with repeated measures, and included a retention test following a two-day weekend break. The experimental design resembles the Transfer of Training Method (Lathan et al., 2002) discussed earlier in Chapter 2, with the addition of the retention test.

The experiment was conducted on 32 subjects during two regularly meeting mechanic training courses in January and March 2002. The subject's scores (elapsed time to complete the tasks, and errors made) on the System Power-up and the Weapon System InterFIT were recorded each training day (See Table 3).

Table 3. Experimental Design Data Collection Schedule

	Wed.	Thurs.	Fri.	Mon.
Task				
System Power-up	S, T	T	T	Re, R, Q
Weapon System InterFIT	S, T	T	T	Re, R, Q

Note. S = Spatial Ability Test, T = Task Training, Re = Recall Test (Appendix H)
R = Task Retention Test on Real Tank, Q = Questionnaires (See next sub-heading)

The control group subjects were scored using the diagnostic software imbedded in the training system. The desktop system tallies subject errors when they fail to follow the task procedure properly. The subjects using the VIMT prototype were manually scored by the experimenter by recording the elapsed time, and number of errors made executing the task. Following the weekend break, the subjects took the retention test on the real M1A2 SEP tank, without the use of the maintenance manual available to them in prior tests.

The subjects were scored on their elapsed time to complete the task, and procedural errors they made during their execution of the Weapon System InterFIT. Additionally, each subject's score on a spatial abilities test taken prior to testing was used to adjust the scores. Regression analysis was conducted on Equation 2 (below) to create an adjusted scores equation:

$$Time = B_0 + B_1 Spatial + B_2 Errors + B_3 VR + B_4 Error \times VR \quad (2)$$

Where VR is a qualitative variable that equals 1 for subjects using the VIMT, and equals 0 for the desktop simulation subjects.

Following the adjustment of the scores according to Equation 2, the adjusted times were analyzed with a test of hypothesis using a *t* statistical test. The *t* test is appropriate because there are only two experimental groups, with a small number of subjects. The *t* test assumptions require that the samples be randomly selected from the target groups, and that the variances of the scores within the two groups are equal. The use of the *t* statistic is valid, assuming the Army randomly selects mechanics for assignment to M1A2 units. In addition, since the mechanics are all sampled from the Army, a single population, it was assumed that the variances in their performances were equal. The null and alternative hypotheses are listed below.

H_0 = There is no difference between adjusted test scores of the group of mechanics using the VIMT, and the group using the desktop simulation. $Time_{Desktop} – Time_{VIMT} = 0$.

H_a = There is a significant difference in average adjusted test scores in favor of the VIMT test group. $Time_{Desktop} – Time_{VIMT} > 0$.

Rejecting the null hypothesis would have indicated that the VIMT group task retention is higher than the task retention of the group using the desktop simulation system.

The average procedural errors made by each group were also analyzed with a *t* statistical test to see if there was a significant difference between the two groups.

In addition, a *t* test would have been utilized to examine the differences between groups for the scores from the training tests. However, a comparison of training trials between the experimental groups was not conducted, due to the very large differences in elapsed time recorded during training trials on the two systems. This large difference is due to the VIMT replicating only the System Power-up and Weapon System InterFIT tasks, while the desktop simulation required that additional tasks be performed prior to executing the Weapon System InterFIT. These additional tasks accounted for the large difference in training trial elapsed time between the two groups of subjects. See tables in Appendix G for the listing of raw scores.

Questionnaires

In addition to the conducting an experimental test of hypothesis, surveys were distributed to the subjects. Before the experiment, each student completed a spatial abilities test, and an information questionnaire. After each exposure to the VIMT, which lasted approximately 15 min (Desktop group average time of exposure was 58 min), the subjects completed a cyber sickness checklist (See Appendix C) to determine the presence of symptoms. Prior to the retention test, the subjects completed a recall test, requiring them to identify twenty various turret components of the M1A2 SEP tank depicted in photographs of the turret. Following the retention test, the subjects filled out two different Presence Questionnaires. One presence questionnaire was the Witmer and Singer Ver. 3.0, the other was the 1994 Slater, Usoh, and Steed. Each subject completed the presence questionnaires in random order. See Appendices D and E.

CHAPTER FOUR: RESULTS

The result from analysis of the data collected is that there is no significant difference in the adjusted retention test scores (Task performance times) between the virtual reality group and the desktop simulation group, $t = 0.45$, $p = .328$. The results are shown in Table 4, Table 5, and Table 6.

Table 4. Descriptive Statistics of Retention Test Elapsed Times (in minutes)

Group	*n*	*M*	*Mdn*	*Trimmed M*	*SD*
Desktop	16	6.907	6.255	6.781	1.591
VIMT	16	6.778	7.05	6.795	1.485

Note. The Trimmed Mean is calculated by removing the smallest and largest 5%, and calculating the mean of the remaining values.

The results in Table 4 indicate a small difference exists between the means for experimental group raw times taken from the retention test (See Table G-5 in Appendix G). Regression of the raw data according to Equation 2 yielded the adjusted score equation, Equation 3, below.

$$Time = 6.92 - 0.145 Spatial + 0.771 Error - 0.215 VR - 0.416 Error \times VR \qquad (3)$$

Table 5 (below) lists the results from the linear regression that produced Equation 3, the adjusted scores equation.

Table 5. Results of Linear Regression for Time to Complete Task. From Equation 3 (Adjusted Score Equation)

Variable	*B*	*SE B*	*p*
Constant	6.9175	0.2288	.000
Spatial Ability	-0.1452	0.2379	.547
Error	0.7708	0.2348	.003
VR	-0.2153	0.2290	.355
Error X VR	-0.4158	0.2404	.095

Analysis of Variance

Source	*df*	*SS*	*MS*	*F*	*p*
Regression	4	27.574	6.894	4.27	.008
Resid. Error	27	43.594	1.615		
Total	31	71.168			

Note. $SD = 1.271$, $R^2 = 38.7\%$, $R^2_{(adj)} = 29.7\%$

Data from the raw scores in Appendix G was then processed through Equation 3 to yield the adjusted score for each subject. The time differences seen in the raw data were still evident following adjustment of the scores using Equation 3. A one-tailed, *t* test of these adjusted scores (See Table 6, below for complete data) found no significant difference between the two groups of subjects (t = 0.46, p = .674).

Table 6. Upper Tail *t* Test Analysis of Adjusted Time to Complete Task

Group	*n*	*M*	*SD*	*SE M*
Desktop	16	6.984	0.871	0.22
VIMT	16	6.856	0.729	0.18

Note. t = 0.45, p = .328, df = 30. $H_a = \mu_{Desktop} - \mu_{VIMT} > 0$. SD_{pooled} = 0.328.
The equation used to adjust the scores was Equation 3, previous page.

The VIMT group did not score higher than the Desktop group on the Slater, Usoh, and Steed (SUS) Presence Questionnaire (PQ) (Not significant at t = -0.37, p = .356), but did on the Witmer and Singer (WS) PQ (Significant at t = -2.49, p = .01). See Tables 7 and 8, below. The SUS PQ asks more questions about the degree of departure from the real world environment, while the WS PQ queries the quality of the user's interaction in the VE. Judging from the results, the subjects indicate that the VR trainer presents a more realistic interaction with the environment than the desktop simulation, but that the VR trainer does not completely engross them in the artificial world.

Table 7. SUS Presence Questionnaire Score Lower-tail *t* Test Results

Group	*n*	*M*	*SD*	*SE M*
Desktop	13	3.82	1.38	0.38
VIMT	15	3.981	0.804	0.21

Note. $t = -0.37$, $p = .356$, $df = 26$, $H_a = \mu_{Desktop} - \mu_{VIMT} < 0$. $SD_{pooled} = 1.11$. The higher the score, the higher the sense of presence on a scale of 1 to 7.

Table 8. WS Presence Questionnaire Lower-tail *t* Test Results

Group	*n*	*M*	*SD*	*SE M*
Desktop	13	4.45	1.21	0.34
VIMT	16	5.529	0.928	0.23

Note. $t = -2.49$, $p = .010$, $df = 27$, $H_a = \mu_{Desktop} - \mu_{VIMT} < 0$. $SD_{pooled} = 1.06$. The higher the score, the higher the sense of presence on a scale of 1 to 7.

The experimental group averages from the WS Presence Questionnaire, The SUS Presence Questionnaire, and the groups' raw retention test performance times were tested for correlation and are presented in Table 9, below. There is no significant correlation between the VR group's performance times and the PQs, indicating no relationship exists between the performance times and the PQ scores. The correlation between the desktop group's performance times and their PQ scores is slightly stronger, but still insignificant. There is a slightly larger correlation between the times of both groups and the WS PQ, than with the SUS PQ.

Table 9. Correlation between Raw Retention Test Performance Times and PQ Scores.

Group	SUS PQ	WS PQ
Desktop		
Correlation	-.201	-.441
p value	.510	.131
VIMT		
Correlation	-.118	-.186
p value	.675	.490

Note. Although insignificant in this case, negative correlation would indicate that Higher PQ scores may be related to faster performance times.

The correlation between the training time improvement between the first and second training trials is displayed in Table 10, below. There is a strong correlation between the individual improvement for the desktop group and the individual scores from both PQs, indicating a possible positive relationship between the two. That positive relationship would mean that higher PQ scores would relate to larger improvements in performance times. The correlation between the VR group improvement times and their respective PQ scores is weak. However, training trial times of the desktop group were on average 58 minutes, while the VR group averaged about 15 min. Their respective improvements were 17.1 min and 3.63 min. The desktop group thus had a lot of room to improve—this large improvement no doubt positively affected the correlation of the desktop group.

Table 10. Correlation between Training Time Improvement and PQ Scores.

Group	SUS PQ	WS PQ
Desktop		
Correlation	.854	.929
p value	.030	.002
VIMT		
Correlation	-.236	.270
p value	.397	.311

Note. Positive correlation between both PQs and the Desktop group improvement in training performance scores indicates that increased PQ scores appear to be related to increased improvement of training performance times.

The results from the 20 question recall test (See Table 11, below) administered prior to the retention test indicate that there is not a significant difference between the scores of the desktop group and the VR group ($t = 0.79$, $p = .222$). The recall test figures appear in Appendix H.

Table 11. Recall Test *t* Test Results

Group	*n*	*M*	*SD*	*SE M*
Desktop	10	17.5	1.51	0.48
VIMT	10	16.7	2.83	0.90

Note. $t = 0.75$, $p = .222$, $df = 13$, $H_a = \mu_{\text{Desktop}} - \mu_{\text{VIMT}} > 0$. $SD_{pooled} = 1.06$

Of the 16 VR subjects, 9 reported symptoms of cyber sickness during training with the VIMT. None of the participants felt they needed to cease training due to discomfort, nor complained of symptoms during training. A numerical tally of reported symptoms and their seriousness is below in Table 12.

Table 12. Tallied Number and Severity of VR Group Cyber Sickness Symptoms

Symptom	Severity		
	Slight	Moderate	Severe
General Discomfort	2		
Fatigue	1		
Headache/Neck Strain	3		
Eye Strain	5	1	
Difficulty Focusing	2	2	
Increased Salivation			
Sweating	1		
Nausea	1		
Difficulty Concentrating	2		
Fullness of Head	4		
Blurred Vision	2		
Dizzy (Eyes Open)			
Dizzy (Eyes Closed)	1		
Vertigo			

Note. n = 16. Symptoms taken from Cyber Sickness Checklist, Appendix C.

The number of procedural errors made by the VR group during the retention test was not significantly different (See Table 13, below) from the number of procedural errors made by the desktop group (t = 1.02, p = .315).

Table 13. One-tailed t Test Results of Retention Test Procedural Errors

Group	*n*	*M*	*SD*	*SE M*
Desktop	16	1.38	1.45	0.36
VIMT	16	1.88	1.31	0.33

Note. $t = 1.02$, $p = .315$, $df = 30$, $H_a = \mu_{Desktop} - \mu_{VIMT} = 0$. $SD_{pooled} = 1.38$

The interaction of procedural errors and the VR qualitative variable yielded a relatively high p value in the regression of Equation 2 (p = .095). The interaction term's coefficient also has the second highest value in the regressed equation (B_4 = -0.416). Graphing the interaction (See Figure 3, below), the mean performance times of VR group had a smaller variance than did the mean times of their desktop-trained counterparts.

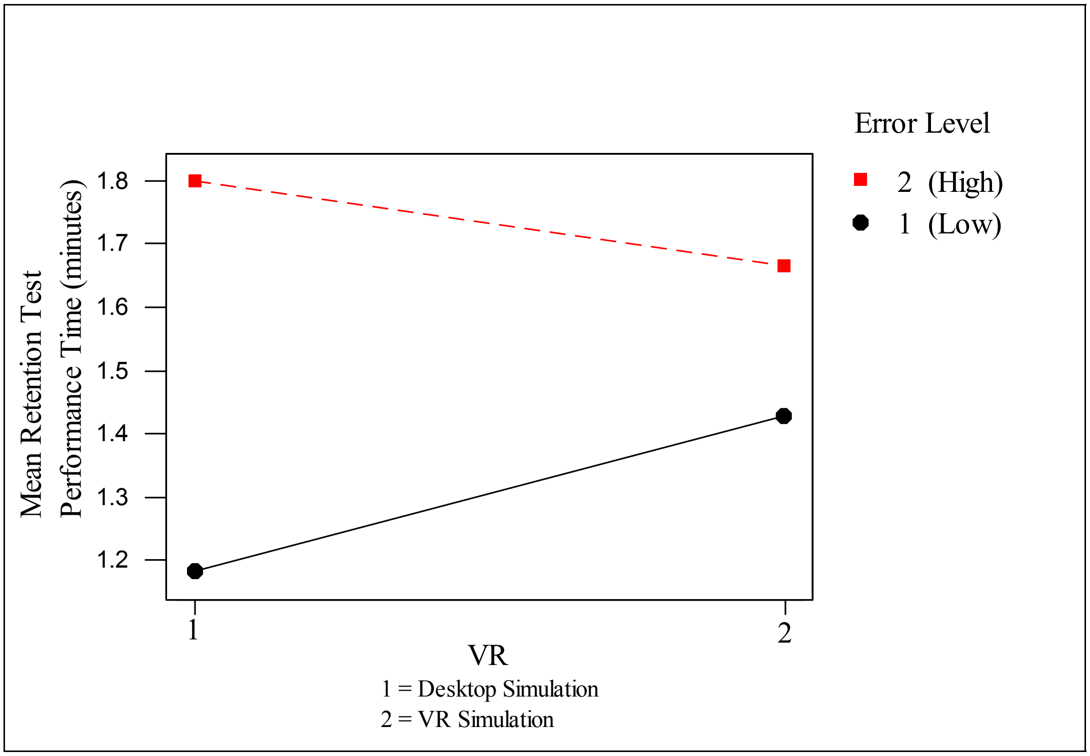

Figure 3. Interaction of Error and VR Variables with Respect to Performance Time

CHAPTER FIVE: DISCUSSION

The results from the statistical analysis do not significantly support the hypothesis that VR increases retention of the trained task in this case. A small difference was found between the times to perform the transfer task for the two experimental groups.

The procedural errors made by the two groups of subjects during the retention test are not significantly different, but the VR group made slightly more errors. These errors may have had a detrimental effect on the VR group's performance time during the test.

The interaction of the VR variable with the number of retention test errors showed that the VR group had less variance in their retention test performance times than did the desktop group. A possible explanation of this result may be the increased specificity of location cues in the VR model. The VR subjects were required to reach out to the actual switch or lever location to operate the selected mechanism, while the desktop group maneuvered a mouse on a flat desk to perform the same function. That increased realism of the VR experience may aid in retrieval of location cues from memory, and be the cause of the decreased variance in the VR group performance times. This increased consistency in performance may be an added benefit of VR training. However, in this case, the difference in the overall performance times between the two groups, and their relation to the ACT-R model (Anderson & Lebiere, 1998) was still the overarching concern of the study.

The VR group recorded significantly higher Witmer and Singer PQ scores (t = -2.49, p = .010) than did the desktop group. The differences between the two experimental groups on the Slater, Usoh, and Steed PQs was not significant (t = -0.37, p = .356). The higher Witmer and Singer PQ scores of the VR group indicate that the group experienced higher levels of presence than did those using the desktop simulation. The difference in presence between the experimental groups did not seem to have a significant effect on their retention test time and errors, however. The WS PQ asks more questions as to the quality of the interaction with the VE, while the SUS PQ asks more questions as to the user's feeling of departure from the real world, and inclusion in the VE. Therefore, while the quality of the interaction was better in the VR than in the desktop simulation, the subjects did not significantly feel more excluded from the real world and immersed in the artificial environment than did the group using the desktop simulation.

The subjects that participated in the experiment are not novices on the M1 series tank. Although at the time of the experiment, they were new to the specific model of the vehicle, the M1A2 SEP, the subjects had been training on the earlier models for over 4 months and were well acquainted with the layout of the systems and panels in the turret. Since a good portion of the advantages of VR is in spatial knowledge, the differences between the experimental groups may not be so evident when both groups have prior knowledge of the environment. This factor of prior experience may be one of the reasons why the differences in presence scores between the two groups did not manifest itself in the groups' adjusted scores. The activation of the memory elements in the VR group versus the desktop group may have been different, but the interference generated by prior training may have masked the difference, resulting in statistically similar scores. A study using subjects with no prior knowledge of the M1 tank may yield differences that are more significant.

However, despite their prior experience, there is a slight advantage for the VR trained group in performance times during the retention test.

From the standpoint of experienced trainees, it is evident that a VR trainer would have a greater effect if used earlier in the training evolution. As with the VR M1 Tank Driver Trainer currently in use to train tank drivers, the students drive in the VR trainer prior to operating the real world vehicle. The driver trainer would likely have a smaller impact on a trained tank driver. Since there is currently no plan to change the training evolution of the M1 tank mechanic program, where mechanics progress from the oldest model of the tank to the newest model, there appears to be less value in using a VR maintenance trainer late in the curriculum. With the current training program, the subjects used in this experiment were taken from the target population of mechanics, and a fielded system placed into this program would likely produce performance results similar to those found in this experiment.

The maintenance task selected for this study is not the type of task normally trained in VR. Navigational tasks are typically selected for training in virtual reality because such tasks require a large degree of spatial awareness, something VR presents with realistic accuracy. The Weapon System InterFIT requires some spatial knowledge of the interior layout of the M1A2 SEP Tank turret, but mostly the knowledge required by the task is procedural in nature. Although procedural tasks can be trained in VR, experience has shown that performance of such tasks in VR may not significantly differ than that in less expensive simulation environments, such as desktop simulation. See Table 14 for a comparison of tasks and their respective demands.

There are cost considerations when fielding a VR training system versus a desktop training system. The addition of an HMD and tracking system to a desktop trainer increases the unit cost more than $10 thousand. This does not include the additional cost of any proprietary software that must be purchased or developed for the VR equipment to operate properly. The desktop simulation obviously has the advantage of relying on simple, relatively inexpensive technology. Given no significant difference in the performance of a VR simulation and a desktop simulation, the desktop simulation would be the better choice from a purely fiscal standpoint.

Table 14. Appropriateness of Training Tasks for Training in Virtual Reality

Task Types	Primary Task Demands	Appropriateness for VE Training	Rationale
Navigation	Spatial Knowledge of Environment	High	Spatial Knowledge main added value of VR
Forestry Operations	Eye-hand coordination / Use of Controls	Medium	Less use of spatial knowledge. Natural interface assists in task
Maintenance	Procedural Knowledge of Task	Low	Procedural knowledge more easily replicable by other means

Cyber sickness was not a factor in the execution of the experiment. Although 9 of the 16 VR reported “slight” to “moderate” symptoms of cyber sickness following exposure (See Table 12, Chapter 3) none felt that they could not continue with the training. The HMD used in the study could be adjusted for IPD and viewing angle. It did not have a diopter adjustment, but did accommodate the wear of eyeglasses. This lack of focusing adjustment likely created some eyestrain among the subjects over time. The HMD used did have sufficient resolution to see all of the text displayed inside the tank. One subject initially reported the inability to read the labeling inside the environment, but when the subject wore his glasses to correct his astigmatism, he reported no vision problems. If the VIMT were fielded to replace desktop systems, it would be recommended that the HMD used in the permanent system have adjustments for diopter power, as well as IPD and viewing angle (Menozzi, 2000). In addition, the fielded system should have the ability to be used without a HMD, so that an instructor or subject not able to wear HMDs can operate the system without difficulty. A controller such as a Logitech® Spaceball® would work quite well as a backup controller to navigate though the 3D space.

The experiment performed may have been enhanced by a larger number of training sessions, and by a longer delay period between training and the retention test. The larger number of training sessions would allow increased activation of the memory elements associated with the training task, while the increased delay period would increase the amount of decay present at the time of the retention test. These two improvements may show a significant difference in performance scores between those trained in VR and those trained on desktop simulators. Additionally, as mentioned earlier, use of inexperienced subjects may yield different findings than those found using subjects with prior training on older models of the systems.

The results of the experiment determined that the training conducted on both the VR and desktop systems positively transferred to the real world system. Additionally, the VR system showed that it decreased the variance of performance times of the subjects that used it. However, given the considerable cost differential between the VR and desktop systems, as well as the current evolution of mechanic training in the U.S. Army, the desktop trainer seems to provide better cost benefits.

Although this study did not find a significant difference in the retention between those trained in VR environments, and those trained in desktop simulation environments, it explored a previously unstudied effect of virtual reality on humans. If, after further studies, it were found that virtual reality increases retention of the trained tasks, it would likely cause a shift in training strategies in several industries. Because of its potential importance to the training of personnel, more effort should be applied in the future towards determining the actual effects of VR on memory.

APPENDIX A

Experiment Pre-Brief

Experiment Pre-Brief

You have been selected as a research participant to determine if using a virtual reality simulator versus a desktop simulator increases retention of the trained task. Some of you will be immersed in a virtual environment (M1A2 SEP turret) and perform system power-up, and the Weapon System, GPS, Loader's Station InterFIT. Along with regular training, you will receive a pre-test and post-test of the above tasks, and be tested on the two tasks once per day for four days starting today, to assess your skill development. The elapsed time and the errors per task will be measured. Two days following your post-test, you will again be tested on the two above tasks, but in the actual tank, or in the Hands-on Training System (HOTS).

You will also be given several surveys to complete.

Because some of you will be viewing the virtual environment (VE) through a helmet-mounted display (HMD), you may experience motion sickness or eyestrain. If your symptoms become too extreme, stop work and notify an instructor or an experimenter.

If you have questions, do not hesitate to ask an experimenter.

APPENDIX B

Maintenance Task Performance Measures

Table B-1, System Power-up Task Procedures

Step	Procedure Steps	Action	Results
1.	Tank parked, preferable on hard level surface	No action required.	Tank assumed to be on a hard level surface.
2.	Tracks blocked	No action required	Assumed that tracks are blocked
3.	Parking brake set	Click on the parking brake to set, if required.	Parking brake is set. Warning message is displayed.
4.	Batteries serviced	No action required	Assume batteries are serviced.
5.	Turret power on	Press the Master power and Turret power pushbuttons, or press turret power pushbutton.	Turret power is turned on.
6.	All circuit breakers on or in tripped condition	No action required, unless CB were turned off or tripped during verification.	
7.	Commander's Independent Thermal Viewer (CITV) on	Press the CITV power pushbutton. Powers up defaults to Normal, light illuminates at 18 seconds	CITV comes out of the stowed position.
8.	FIRE CONTROL MODE switch on Gunner's Primary Sight (GPS) set to NORMAL	Click on the FIRE CONTROL MODE switch and set to the NORMAL position	FIRE CONTROL MODE switch is placed to the NORMAL position, and light illuminates.
9.	Gun Turret Drive (GTD) switch on Loader's Panel (LP) set to POWERED	Click on the Gun Turret Drive switch and set to the POWERED position	Gun Turret Drive switch is placed to the POWERED position, and light illuminates.

Step	Procedure Steps	Action	Results
10.	Gun and turret locks locked unless directed otherwise by procedure	Click on the gun travel lock and set to the locked position. Click on the turret traverse lock and set to the locked position.	Gun and turret locks are locked.
11.	Main gun positioned over front of vehicle	Using the CCHA, GCH, Manual elevation, place gun over the front of the vehicle.	Main gun is placed over the front of the vehicle. (Over driver's hatch)
12.	Communication system set up for normal operation	Not required	

Table B-2. Weapon System InterFIT Task Procedures

Step	Procedure Steps	Action	Results
13.		Press the START TEST menu button on the GCDP.	Initial page of GPS Loader's station InterFIT is displayed.
14.		1. Click on the MAIN GUN SAFE/ARMED SWITCH and set to the SAFE position. 2. Click on the GUN/TURRET DRIVE SWITCH and set to MANUAL. 3. Click on the TURRET BLOWER SWITCH and set to OFF. 4. Click on the FIRE CONTROL MODE SWITCH and set to NORMAL. 5. Click on the GUN SELECT TRIGGER and set to TRIGGER SAFE. 6. Click on the DEFROSTER SWITCH and set to OFF. 7. SELECT DONE MENU KEY.	MAIN GUN SAFE/ARMED SWITCH is set to the SAFE position. GUN/TURRET DRIVE SWITCH is set to MANUAL. TURRET BLOWER SWITCH is set to OFF. FIRE CONTROL MODE SWITCH is set to NORMAL. GUN SELECT TRIGGER is set to TRIGGER SAFE. DEFROSTER SWITCH and set to OFF. Next menu is displayed

Step	Procedure Steps	Action	Results
15.		1. Click on the TURRET BLOWER SWITCH to set to ON. 2. Click on the GUN/TURRET DRIVE to set to POWERED. 3. Click on the GPS DEFROSTER SWITCH to set to ON. 4. Click on the MAIN GUN SAFE/ARMED LEVER to set to ARM. 5. SELECT MENU DONE KEY	TURRET BLOWER SWITCH is set to ON. GUN/TURRET DRIVE is set to POWERED. GPS DEFROSTER SWITCH is set to ON. MAIN GUN SAFE/ARMED LEVER is set to ARM. Next menu is displayed.
16.		Press YES or NO for defroster light status.	
17.		1. Click on the TURRET BLOWER SWITCH to set to OFF 2. Click on the GUN/TURRET DRIVE SWITCH to set to EL UNCPL 3. Click on the GPS DEFROSTER SWITCH to set to OFF 4. Click on the MAIN GUN SAFE/ARMED LEVER to set to SAFE SELECT DONE MENU KEY	TURRET BLOWER SWITCH is set to OFF. GUN/TURRET DRIVE SWITCH is set to EL UNCPL. GPS DEFROSTER SWITCH is set to OFF MAIN GUN. SAFE/ARMED LEVER is set to SAFE. Next menu is displayed.

Step	Procedure Steps	Action	Results
18.		1. Click on the SABOT SWITCH. 2. Click on the HEAT SWITCH. 3. Click on the AIR/GROUND SWITCH 4. Click on the STAFF SWITCH. 5. Click on the MPAT SWITCH. 6. Click on the LIGHTS TEST SWITCH. Press DONE menu key.	SABOT LIGHT is illuminated. HEAT is illuminated. AIR/GROUND LIGHT is illuminated STAFF LIGHT is illuminated MPAT LIGHT is illuminated. All lights on the Loader's Panel and GPS are illuminated. Next menu is displayed.
19.		Click on the GUN SELECT SWITCH and set to MAIN and then release. Press DONE menu key.	GUN SELECT SWITCH is set to MAIN. MAIN GUN SELECT lamp illuminates. Next menu is displayed.
20.		Click on the GUN SELECT SWITCH and set to COAX and then release. Press DONE menu key.	GUN SELECT SWITCH is set to COAX. COAX GUN SELECT lamp illuminates. Next menu is displayed.

Step	Procedure Steps	Action	Results
21.		Click on the FIRE CONTROL MODE and set to EMERGENCY and then release. Press DONE menu key.	FIRE CONTROL MODE SWITCH is set to EMERGENCY. FIRE CONTROL MODE EMERGENCY lamp illuminates. Next menu is displayed
22.		Click on the FIRE CONTROL MODE and set to MANUAL and then release. Press DONE menu key.	FIRE CONTROL MODE SWITCH is set to MANUAL. FIRE CONTROL MODE MANUAL lamp illuminates. Next menu is displayed
23.		Click an drag the PANEL LIGHTS KNOB fully clockwise *SELECT DONE MENU KEY*	All lights are illuminated.
24.	ARE ANY FC MODE OR GUN SELECT MODE LAMPS LIT?	*Press YES to answer question*	Next menu is displayed
25.	ARE ANY LAMPS ON THE LOADER PANEL LIT?	*Press YES to answer question*	Next menu is displayed

Step	Procedure Steps	Action	Results
26.	LAMP CHECK MAIN GUN ARMED MAIN GUN SAFE GUN/TURRET DRIVE EL UNCPL GUN/TURRET DRIVE POWERED GUN/TURRET DRIVE MANUAL	*Press YES for each lamp, and then press DONE*	Next menu is displayed
27.	LAMP CHECK SABOT MPAT AIR GROUND STAFF HEAT	*Press YES for each lamp, and then press DONE*	Next menu is displayed

APPENDIX C

Cyber Sickness Symptom Checklist

Cyber Sickness Symptom Checklist

Format and some content checklist from Burns & Patrey (2000).

Participant Name _____________ Date_____________

Before Training_________ After Training_________ (Check only ONE)

Duration spent using head-mounted visual display today (in minutes): _______________

Instructions: Please circle the severity of any symptoms that apply to you right now.

1.	General Discomfort	None	Slight	Moderate	Severe
2.	Fatigue	None	Slight	Moderate	Severe
3.	Headache/Neck Strain	None	Slight	Moderate	Severe
4.	Eye Strain	None	Slight	Moderate	Severe
5.	Difficulty Focusing	None	Slight	Moderate	Severe
6.	Increased Salivation	None	Slight	Moderate	Severe
7.	Sweating	None	Slight	Moderate	Severe
8.	Nausea	None	Slight	Moderate	Severe
9.	Difficulty Concentrating	None	Slight	Moderate	Severe
10.	Fullness of Head*	None	Slight	Moderate	Severe

*Fullness of head means internal pressure in head, similar to sinus pressure, such as one gets when hanging upside down from the monkey bars

11.	Blurred Vision	None	Slight	Moderate	Severe
12.	Dizzy (Eyes Open)	None	Slight	Moderate	Severe
13.	Dizzy (Eyes Closed)	None	Slight	Moderate	Severe
14.	Vertigo**	None	Slight	Moderate	Severe

**Vertigo is a disordered state in which the person or his/her surroundings seem to whirl dizzily; loss of orientation that makes it difficult to perceive which way is up

Are there any other symptoms that you are experiencing right now? If so, please describe the symptom(s) and rate their severity on the other side.

APPENDIX D

Witmer and Singer Presence Questionnaire

WS Presence Questionnaire

(Witmer & Singer, Ver. 3.0, Nov. 1994)

Soldier Name:____

Characterize your experience in the environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

WITH REGARD TO THE EXPERIENCED ENVIRONMENT

1. How much were you able to control events?

|________|________|________|________|________|________|________|

NOT AT ALL SOMEWHAT COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|________|________|________|________|________|________|________|

NOT RESPONSIVE MODERATELY RESPONSIVE COMPLETELY RESPONSIVE

3. How natural did your interactions with the environment seem?

|________|________|________|________|________|________|________|

EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

4. How much did the visual aspects of the environment involve you?

|________|________|________|________|________|________|________|

NOT AT ALL SOMEWHAT COMPLETELY

5. How much did the auditory aspects of the environment involve you?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

6. How natural was the mechanism that controlled movement through the environment?

|________|________|________|________|________|________|________|

EXTREMELY ARTIFICIAL	BORDERLINE NATURAL	COMPLETELY NATURAL

7. How compelling was your sense of objects moving through space?

|________|________|________|________|________|________|________|

NOT AT ALL COMPELLING	MODERATELY	VERY COMPELLING

8. How much did your experiences in the virtual environment seem consistent with your real world experiences?

|________|________|________|________|________|________|________|

NOT CONSISTENT	MODERATELY CONSISTENT	VERY CONSISTENT

9. Were you able to anticipate what would happen next in response to the actions that you performed?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

10. How completely were you able to actively survey or search the environment using vision?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

11. How well could you identify sounds?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

12. How well could you localize sounds?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

13. How well could you actively survey or search the virtual environment using touch?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

14. How compelling was your sense of moving around inside the virtual environment?

|________|________|________|________|________|________|________|

NOT COMPELLING	MODERATELY COMPELLING	VERY COMPELLING

15. How closely were you able to examine objects?

|________|________|________|________|________|________|________|

NOT AT ALL	PRETTY CLOSELY	VERY CLOSELY

16. How well could you examine objects from multiple viewpoints?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	EXTENSIVELY

17. How well could you move or manipulate objects in the virtual environment?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT EXTENSIVELY

18. How involved were you in the virtual environment experience?

|________|________|________|________|________|________|________|
NOT INVOLVED MILDLY INVOLVED COMPLETELY ENGROSSED

19. How much delay did you experience between your actions and expected outcomes?

|________|________|________|________|________|________|________|
NO DELAYS MODERATE DELAYS LONG DELAYS

20. How quickly did you adjust to the virtual environment experience?

|________|________|________|________|________|________|________|
NOT AT ALL SLOWLY LESS THAN ONE MINUTE

21. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

|________|________|________|________|________|________|________|
NOT PROFICIENT REASONABLY PROFICIENT VERY PROFICIENT

22. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

|________|________|________|________|________|________|________|
NOT AT ALL INTERFERED SOMEWHAT PREVENTED TASK PERFORMANCE

23. How much did the control devices interfere with the performance of assigned tasks or with other activities?

|________|________|________|________|________|________|________|

NOT AT ALL	INTERFERED SOMEWHAT	INTERFERED GREATLY

24. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

25. How completely were your senses engaged in this experience?

|________|________|________|________|________|________|________|

NOT ENGAGED	MILDLY ENGAGED	COMPLETELY ENGAGED

26. To what extent did events occurring outside the virtual environment distract from your experience in the virtual environment?

|________|________|________|________|________|________|________|

NOT AT ALL	MODERATELY	VERY MUCH

27. Overall, how much did you focus on using the display and control devices instead of the virtual experience and experimental tasks?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	VERY MUCH

28. Were you involved in the experimental task to the extent that you lost track of time?

|________|________|________|________|________|________|________|

NOT AT ALL	SOMEWHAT	COMPLETELY

29. How easy was it to identify objects through physical interaction; like touching an object, walking over a surface, or bumping into a wall or object?

|________|________|________|________|________|________|________|

IMPOSSIBLE	MODERATELY DIFFICULT	VERY EASY

30. Were there moments during the virtual environment experience when you felt completely focused on the task or environment?

|________|________|________|________|________|________|________|

NONE	OCCASIONALLY	FREQUENTLY

31. How easily did you adjust to the control devices used to interact with the virtual environment?

|________|________|________|________|________|________|________|

DIFFICULT	MODERATE	EASILY

32. Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent?

|________|________|________|________|________|________|________|

NOT CONSISTENT	SOMEWHAT CONSISTENT	VERY CONSISTENT

APPENDIX E

Slater, Usoh, Steed Presence Questionnaire

SUS Presence Questionnaire

(Slater, Usoh, Steed, 1994)
Part A

A2: The following describes my educational level:

Educational Level	**Please tick against your answer**
1. GED	
2. High School Graduate	
3. Some College	
4. Associate's Degree	
5. Bachelor's Degree	
6. Graduate Student	
7. Master's Degree	

A3. Have you experienced "virtual reality" (M1 driver's trainer, or other immersive environments) before?

I have experience virtual reality	**Please tick against your answer**
1. never before	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. a great deal	7

A4. To what extent do you use a computer in your daily activities?

I use a computer...	**Please tick against your answer**
1. not at all	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much so	7

A5. Think about some other place you've been today (e.g., your home, barracks room, car, or any other place).
What is the place you are thinking of?..

A6. The following questions relate to the characteristics *of how you are thinking about that place.*

(a) In you're mind's eye, do you see an image of yourself in that place, or do you see that place from the same perspective as when you were there?

	Tick
I see myself there	
I see the place as if I were there	

(b) Think about your present internal *visual image of that place*, and answer each of the following questions:

Circle one item in each row:

Is it in color or monochrome?	mono	color	
Is it larger or smaller than real?	smaller	about the same	larger
Is it nearer or further than real?	nearer	about the same	further
Is it in stereo or mono?	mono	stereo	
Is there a frame around it?	no frame	frame	
Is it all around you (panoramic)?	not panoramic	panoramic	
Is it darker or brighter than real?	darker	about the same	brighter

Questionnaire Part B

The following questions relate to your experience in your virtual reality session only.

B0. Before you entered the 'virtual reality' you were asked to say 'Now' whenever you became aware of a transition from the virtual environment to the real world of the lab.

(a) If you reported *no or very few* such transitions, what was the reason for this?

	Please tick against your answer
1. I rarely experienced being 'in' the virtual world, and so didn't have much chance to come back to reality.	
2. I experience myself as 'in' the virtual world almost all the time, and so rarely came back to reality.	
3. I did experience many transitions from virtual to real but forgot to report these.	
4. Other - please explain:	

(b) If you did make transitions from virtual to real, whether or not you reported these at the time, what do you remember as the causes of the transitions? (For example, hearing an unexpected noise from the real lab might cause such a transition).

B1. Please rate the extent to which you were aware of background sounds in the real classroom in which this experience was actually taking place. Rate this on the following scale from 1 to 7 (where for example 1 means that you were hardly aware at all of the background sounds):

While in the virtual reality I was aware of background sounds from the classroom:	**Please tick against your answer**
1. not at all ...	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much ...	7

B2. How dizzy, sick or nauseous did you feel resulting from the experience, if at all? Please answer on the following 1 to 7 scale.

I felt sick or dizzy or nauseous during or as a result of the experience...	**Please tick against your answer**
1. not at all	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much so	7

B3. Please rate *your sense of being in the tank*, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a place*.

I had a sense of "being there" in the tank:	**Please tick against your answer**
1. not at all ...	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much ...	7

B4. To what extent were there times during the experience when the tank became the "reality" for you, and you almost forgot about the "real world" of the classroom in which the whole experience was really taking place?

There were times during the experience when the virtual tank became more real for me compared to the "real world"...	**Please tick against your answer**
1. at no time	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. almost all of the time	7

B5. When you think back about your experience, do you think of the tank more as *images that you saw*, or more as *somewhere that you visited*? Please answer on the following 1 to 7 scale.

The virtual tank seems to me to be more like...	**Please tick against your answer**
1. images that I saw	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. tanks that I have been in	7

B6. During the time of the experience, which was strongest on the whole, your sense of being in the tank, or of being in the real world of the classroom?

I had a stronger sense of being in...	**Please tick against your answer**
1. the real world of the classroom	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. the virtual reality of the tank turret	7

APPENDIX F

Research Participant Information Questionnaire

ID _________ Date

Research Participant Information Questionnaire

Adapted from Finkelstein (1999)

Please fill in the blank or circle the appropriate response.

1. What is your age? _____years
2. What is your gender? female male
3. Are you in a state of good physical fitness? yes no
4. How many hours did you sleep last night? _____ hours

   4a. Was your sleep sufficient? yes no

5. Circle below the types of medications/substances you have used in the last 24 hours:

   0 – none

   1 – sedatives or tranquilizers

   2 – aspirin, Tylenol, other analgesics or "pain killers"

   3 – anti-histamines

   4 – decongestants

   5 – other ____

6. Have you ever experienced motion or car sickness? yes no
7. How susceptible to motion or car sickness do you feel you are?

0	1	2	3	4	5	6	7
not susceptible	very mildly			average			very highly

8. Do you have a good sense of direction? yes no
9. How many hours a week do you use computers? _____ hours per week.

10. My level of confidence in using computers is

1	2	3	4	5
low		average		high

11. I am ______ at playing video and computer games (home or arcade).

1	2	3	4	5
bad		average		good

12. I enjoy playing video and computer games

1	2	3	4	5
disagree		unsure		agree

13. How many hours a week do you play video or computer games? ____ hours per week.

14. How many times in the last year have you experienced a virtual reality game or entertainment? (CCTT, immersive systems) _______

15. Do you have normal or corrected to normal 20/20 vision? yes no

16. Are you color blind? yes no

APPENDIX G

Scores and Personal Data

Table G-1. Subject Personal Data

Subject	VR[a]	AGE	Hours of Sleep Night Before Test	History of Motion Sickness	Perceived Susceptibility to Motion Sickness[b]
1	1	29	6	N	0
2	1	20	8	N	0
3	1	20	7.5	N	0
4	1	20	7.5	N	2
5	1	21	6	N	0
6	1	18	7	N	0
7	1	20	7	Y	1
8	1	22	7	N	0
9	1	19	7	Y	1
10	1	18	6	N	0
11	1	32	6	Y	1
12	1	19	5	N	0
13	1	19	6	N	0
14	1	23	5	N	0
15	1	18	8	N	0
16	1	22	7	N	0
17	0	32	5	N	0
18	0	19	6	Y	1
19	0	21	6	N	0
20	0	18	4	N	0
21	0	20	7	Y	1
22	0	21	8	N	0

Subject	VR[a]	AGE	Hours of Sleep Night Before Test	History of Motion Sickness	Perceived Susceptibility to Motion Sickness[b]
23	0	22	8	Y	2
24	0	18	7	N	0
25	0	19	7	N	0
26	0	19	7	N	5
27	0	23	7	N	0
28	0	19	7.5	N	0
29	0	18	7	N	2
30	0	20	7	N	0
31	0	19	8	N	0
32	0	21	7.5	N	0

Note: Personal Data (Taken from completed Appendix F. Participant Questionnaire)
[a]Value of 1= Assigned to Virtual Reality Experimental group; 0 = Assigned to Desktop Simulation Experimental Group.
[b]The subjects were asked to report their perceived susceptibility to motion sickness on a 0 to 7 scale, with 0 representing “not susceptible,” and 7 representing “very highly” susceptible.

Table G-2. Subject Personal Data (Cont.)

Subject #	Computer Use (hr/wk)	Computer Game Skill[a]	Computer Games Played (hr/wk)	Vision correctable to 20/20?
1	5	4	1	ASTIG.
2	5	5	3	Y
3	27.5	4	25	N
4	5	4	5	Y
5	4	5	8	Y
6	5	3	2	Y
7	8	5	2	N
8	4	3	4	Y
9	5	5	2	Y
10	12	5	5	Y
11	6	1	0	Y
12	11	4	2	Y
13	25	4	5	Y
14		3	7.5	Y
15	10	5	10	N
16	10	2	5	Y
17	2	1	0	N
18	1	4	0	Y
19	20	3	0	Y
20	6	3	0	Y
21	5	3	1	Y
22	11	5	30	Y
23	5	3	5	Y
24	11	3	2	Y

Subject #	Computer Use (hr/wk)	Computer Game Skill[a]	Computer Games Played (hr/wk)	Vision correctable to 20/20?
25	10	5	8	N
26		5	10	Y
27	10	3	0	Y
28	18	5	16	N
29	10	5	7	Y
30	8	5	4	Y
31	10	3	10	Y
32	25	4	0	N

Note. [a]Subjects rated their own skill at playing computer games on a scale of 1 to 5, with 1 representing "bad" and 5 representing "good."

Table G-3. Experimental Raw Scores from Training Trials

Subject #	Training Trial 1 Time	Training Trial 2 Time	Training Trial 3 Time	Training Trial 1 Error	Training Trial 2 Error	Training Trial 3 Error
1	16.30	11.00	9.97	1	1	1
2	19.42	11.30	8.66	0	1	0
3	11.18	8.77	7.28	0	0	0
4	12.15	7.78	7.07	2	1	1
5	8.47	7.63	7.42	0	1	0
6	14:24	9:16	-	0	0	-
7	13:16	7:49	-	2	0	-
8	12:42	9:25	-	1	0	-
9	9:46	9:05	-	0	0	-
10	7:04	9:12	-	0	0	-
11	15:35	12:35	-	1	1	-
12	18:05	8:44	-	3	0	-
13	12:40	10:11	-	2	2	-
14	18:42	13:06	-	2	1	-
15	10:55	8:00	-	0	0	-
16	11:20	10:04	-	1	2	-
17	85.00	165.0	180.0	17	1	0
18	100	-	-	2	-	-
19	100	75	-	23	3	-
20	112.0	60.00	50.00	12	5	4
21	42	23	-	0	0	-
22	32	-	-	0		-
23	34	33	37	0	0	8

Subject #	Training Trial 1 Time	Training Trial 2 Time	Training Trial 3 Time	Training Trial 1 Error	Training Trial 2 Error	Training Trial 3 Error
24	18	39	39	0	0	5
25	31	23	-	0	0	-
26	72	23	77	4	0	9
27	26	-	-	8	-	-
28	25	-	-	6	-	-
29	32	-	-	14	-	-
30	99	26	-	6	0	-
31	77	32	-	0	12	-
32	35	-	-	10	-	-

Note. A “-“ denotes trial not executed or missing data

Table G-4. Questionnaire and Spatial Abilities Test Scores

Subject #	Spatial Abilities Test Score[a]	Witmer & Singer Presence Questionnaire (Ver. 3.0) Avg. Score	Slater, Usoh, & Steed Presence Questionnaire (1994) Avg. Score
1	11	4.65	2.57
2	17	6.78	3.14
3	22	6.53	4.71
4	10	6.49	4.43
5	19	6.07	3.71
6	18	4.80	3.43
7	31	5.21	5.00
8	-6	3.92	3.86
9	10	6.19	4.86
10	7	4.50	0.00
11	12	5.03	3.86
12	2	5.66	4.00
13	16	5.94	3.14
14	21	6.70	3.86
15	40	5.80	5.57
16	16	4.20	3.57
17	5	1.91	7.00
18	3	3.51	3.14
19	26	4.65	3.29
20	12	4.68	3.00
21	9	3.44	0.00
22	20	4.06	1.86

Subject #	Spatial Abilities Test Score[a]	Witmer & Singer Presence Questionnaire (Ver. 3.0) Avg. Score	Slater, Usoh, & Steed Presence Questionnaire (1994) Avg. Score
23	19	0.00	0.00
24	19	0.00	1.86
25	18	4.35	3.00
26	18	0.00	0.00
27	26	5.14	4.43
28	6	6.97	4.00
29	10	5.54	4.00
30	29	5.20	5.00
31	25	5.22	4.57
32	26	4.32	4.57

Note. The two presence questionnaires ask several questions about the subjects' feelings of immersion in their experienced environments. The subjects are asked to rate their feelings on a scale of 1 to 7. The score of some questions is reversed to equate that a reply of "7" means a higher level of experienced presence.
[a]The Spatial Abilities Test consists of 42 cube comparisons where the subject must decide if the cubes pictured are two different views of the same cube, or two different cubes. The score is determined by subtracting the number of incorrect answers from the number of correct answers.

Table G-5. Retention Test Scores

Subject #	Raw Retetion Test Performance Time	Retention Test Observed Errors	Adjusted Retention Test Performance Time[a]
1	6.98	3	7.02
2	6.75	2	6.81
3	5.07	3	6.63
4	8	0	7.06
5	4.45	3	6.74
6	7.37	2	6.77
7	7.53	3	6.31
8	7.5	3	7.63
9	6.17	1	7.06
10	4.1	1	7.17
11	9.22	4	6.99
12	7.12	0	7.34
13	5.35	0	6.85
14	8.38	3	6.67
15	5.98	1	5.99
16	8.48	1	6.85
17	6.45	1	7.24
18	10.35	4	7.31
19	6.02	2	6.49
20	6.02	1	6.99
21	10.22	4	7.09
22	8.77	4	6.70
23	6.06	0	6.74

Subject #	Raw Retetion Test Performance Time	Retention Test Observed Errors	Adjusted Retention Test Performance Time[a]
24	5.53	0	6.74
25	6	1	6.77
26	7.15	2	6.77
27	6.53	0	6.49
28	5.22	1	7.20
29	7	1	7.06
30	5.92	1	6.38
31	7.7	0	6.53
32	5.57	0	6.49

Note. [a]Times were adjusted with equation 3, derived from regression analysis of the raw retention test performance times and the spatial abilities test scores.

APPENDIX H

Recall Test

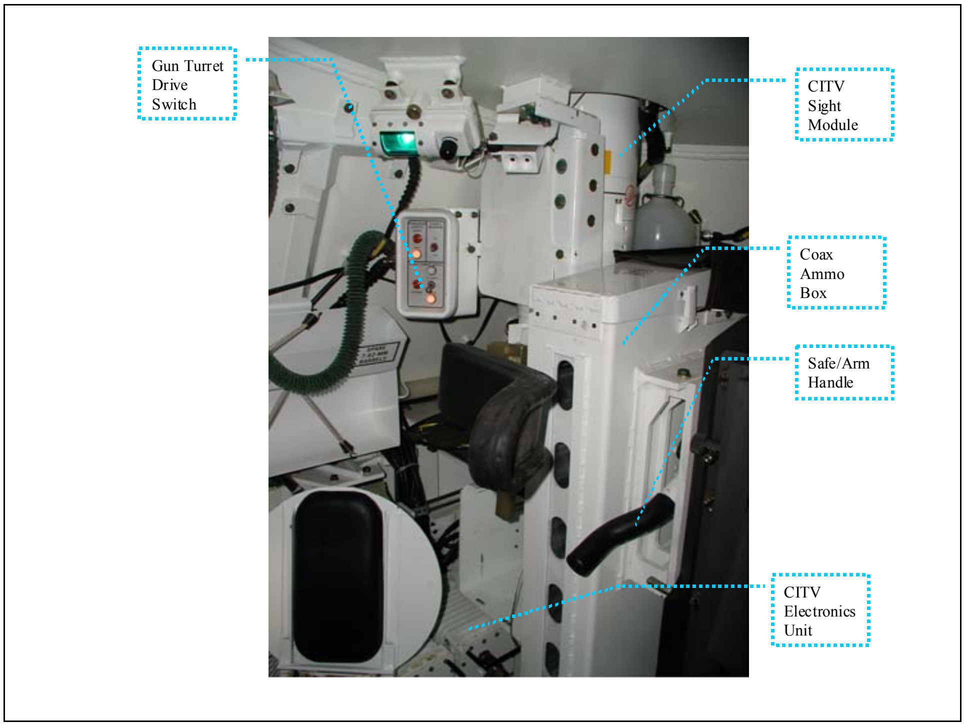

Figure H-1. Page 1 of Recall Test

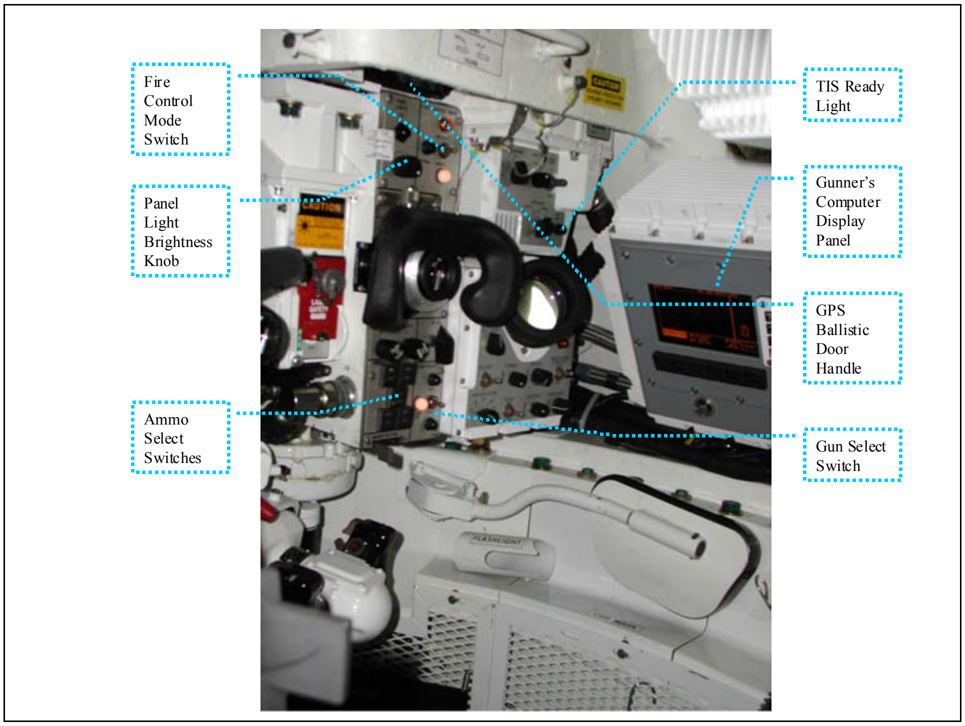

Figure H-2. Page 2 of Recall Test

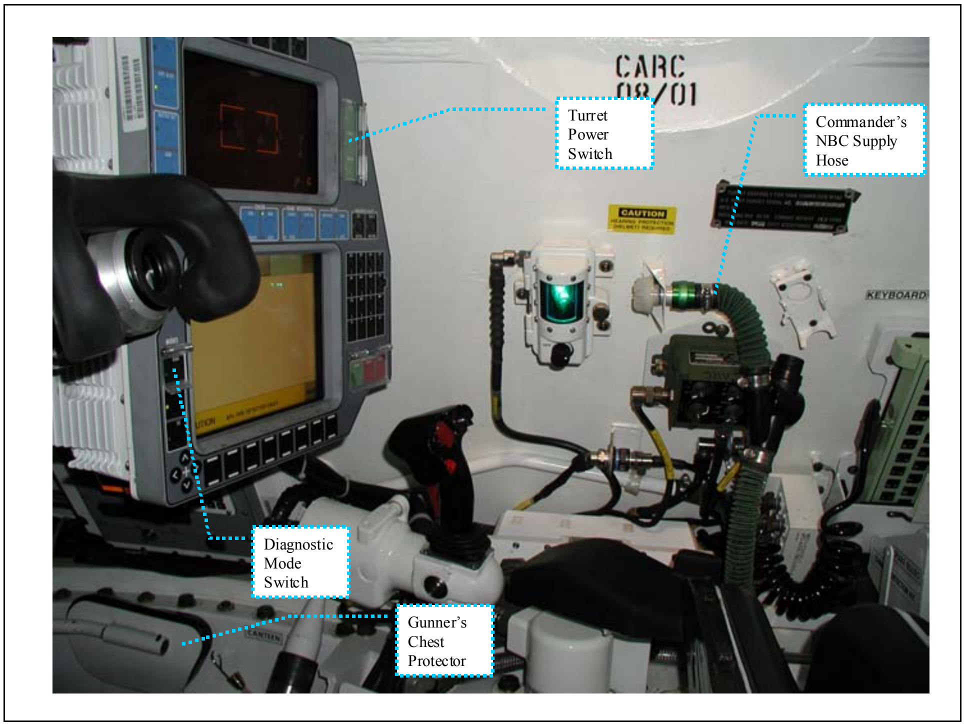

Figure H-3. Page 3 of Recall Test

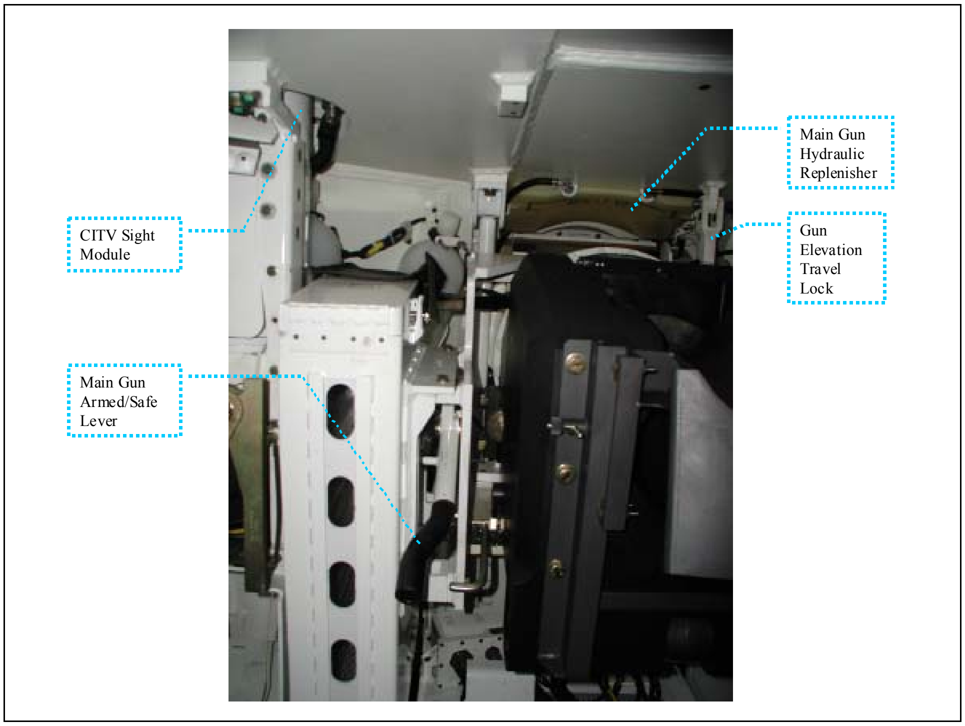

Figure H-4. Page 4 of Recall Test

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